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**13. ABSTRACT *(Maximum 200 words)***

The objective of the project was the design of glucose electrooxidizing anodes and oxygen electroreducing cathodes for a miniature compartment-less and case-less biofuel cell powering sensor-transmitter and receiver-actuator systems implanted in animals. It resulted in the smallest (smaller by a factor of 180 than previously reported) and highest power density (higher by a factor of 5) biofuel cell ever built. The results were obtained in a pH 5 solution in absence of chloride at 37°C and formed the basis for their subsequent extension to physiological conditions after the project ended on Dec 1, 2001.

The anodes were based on the electrical "wiring" of glucose oxidase with redox polymers of low (reducing) redox potentials that connected their redox centers to carbon electrodes. The cathodes were based on the electrical "wiring" of copper enzymes (laccases and bilirubin oxidases) with high (oxidizing) redox potential redox polymers to carbon cathodes. The anodic current densities near 0.1 V (Ag/AgCl) were of ~ 1 mA $cm^{-2}$ and the cathodic current densities were of ~ 3 mA $cm^{-2}$ at ~ 0.5 V (Ag/AgCl).

The smallest biofuel cell built consisted of two 7µm diameter 2 cm long carbon fibers. Its output at 37°C was ~ 1 µW.

**14. SUBJECT TERMS**

Power Sources, Electrochemical, Bio-fuel Cells, Electrodes

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**FINAL REPORT**

Grant #: N00014-97-1-1074

PRINCIPAL INVESTIGATOR: Professor Adam Heller

INSTITUTION: The University of Texas at Austin

GRANT TITLE: Implantable Biofuel Cell Electrodes

AWARD PERIOD: January 1, 1999 - December 31, 2001

OBJECTIVE:
The objective of the project was the design of glucose electrooxidizing anodes and oxygen electroreducing cathodes for a miniature compartment-less and case-less biofuel cell powering sensor-transmitter and receiver-actuator systems implanted in animals.

APPROACH:
The anodes were based on the electrical "wiring" of glucose oxidase with redox polymers of low (reducing) redox potentials that connected their redox centers to carbon electrodes. The cathodes were based on the electrical "wiring" of copper enzymes (laccases and bilirubin oxidases) with high (oxidizing) redox potential redox polymers to carbon cathodes.

ACCOMPLISHMENTS:
The project resulted in the smallest (smaller by a factor of 180 than previously reported) and highest power density (higher by a factor of 5) biofuel cell ever built. The results were obtained in a pH 5 solution in absence of chloride at 37°C. The smallest biofuel cell built consisted of two 7 μm diameter 2 cm long carbon fibers. Its output at 37°C was ~ 1 μW. The cell operated for 3 days, losing 1/10$^{th}$ of its output per day.

CONCLUSIONS:
A compartment-less and case-less miniature power source can be built.

SIGNIFICANCE:
Until now power sources (batteries and fuel cells) required cases, seals and compartment-separating membranes. The project established that a power source can be built without these. The source is based on highly reactant-selective "wired" enzyme anodes and cathodes (so specific that glucose is not oxidized on

the highly oxidizing cathode and oxygen is only very slowly reduced at the highly reducing anode). The compartment-less and case-less cell can be miniaturized to unprecedented dimensions.

PATENT INFORMATION:
"Biological fuel cell and method", *US Patent 6,294,281*, September 25, 2001.

PUBLICATION AND ABSTRACTS (for total period of grant):


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